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Non-Observation Bias in an Address-Register-Based CATI/CAPI Mixed Mode Survey

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Abstract

Landline surveys suffer from an increasing risk of excluding a relevant share of the population. To analyze and correct telephone coverage issues, face-to-face surveys are often used, which contain questions about landline ownership and registration. Others use dual frame approaches and compare results from the landline with another mode. However, such surveys lack information about unobserved sample members.

In this article we analyze representation bias using a household survey with a sample drawn from a population register, where landline is used for households with a matched landline, and face-to-face for those without. We distinguish between the different components of nonobservation, including landline undercoverage, non-contact, and non-cooperation, by either incorporating face-to-face sample members or not, and by the fieldwork phases to recruit households and individuals. Our main interest is how biases from each of these components add up to a final representation bias in the responding sample. In addition, we analyze income and deprivation differences by either including face-to-face sample members or not.

The strongest representation bias in the telephone sample on the household level is caused by telephone undercoverage. The combined sample suffers much less from representation bias, which mostly stems from noncooperation. In terms of income and deprivation differences, our results show that the face-to-face sample is poorer than the telephone sample and needs to be considered for unbiased estimates. Based on these findings we offer some fieldwork recommendations to help reduce selection bias based on the different reasons for nonobservation.

Keywords: mixed mode, telephone number matching, paradata, coverage, contact, cooperation, representation bias

1 Bias from Nonobservation in Surveys with Telephone as the Main Mode

In addition to nonresponse, landline telephone surveys are increasingly challenged by undercoverage (e.g., Peytchev et al., 2011). This latter issue results from a dramatic increase in the proportion of "mobile-only" households (Mohorko et al., 2013; Sala & Lillini, 2014) and an increasing proportion of individuals who no longer wish to be listed in a public directory (Blumberg & Luke, 2014; De Vitiis & Righi, 2011; Ernst Stähli, 2012; Joye et al., 2012; Link & Fahimi, 2013; Sala & Lillini, 2014; Von der Lippe et al., 2011). Landline coverage rates depend on contexts and effort. For example, Brick et al. (2011) used commercial sources to match telephone numbers to a random sample of addresses in the US, and achieved a 57% telephone matching rate. In Switzerland, the Swiss Federal Statistical Office (SFSO) matches register-based samples against its own register of telephone numbers, which includes both publicly listed and unlisted landline numbers. SFSO matching rates of randomly sampled individuals reach an average of 76% (Joye, 2012). A comparable Swiss telephone survey, which is based on register-based samples but uses additional sources of telephone numbers such as commercial databases instead of unlisted landline numbers[1], reports a matching rate of 86% (Lipps & Kissau, 2012).

Undercoverage is compounded by the fact that people with or without a listed landline differ on the basis of socio-demographic information (Busse & Fuchs, 2012; Cobben & Bethlehem, 2005; Lipps & Kissau, 2012; Mohorko et al., 2013; Sala & Lillini, 2014). For example, there is evidence that people without a landline are more likely to be men, living alone, who are young and foreign (Lipps & Kissau, 2012;, Link et al., 2007; Schneiderat & Schlinzig, 2012), Consequently, landline surveys tend to overrepresent women, older people, those with a low or a high education level (students), and households without children (Sala & Lillini, 2014). In addition, there is evidence of substantive variables bias (Joye et al., 2012; Sala & Lillini, 2014) in landline surveys, including for example, an overrepresentation of people who are more satisfied with their lives (Mohorko et al., 2013). Others identify more homeowners (Sala & Lillini, 2014), fewer people who live below the poverty threshold (Safir & Goldenberg, 2008), fewer minority respondents (Holbrook et al., 2003), and a higher average household income (Gordoni, 2010; Holbrook et al., 2003; Schneiderat & Schlinzig, 2012).

1 The SFSO does not provide unlisted telephone numbers to commercial survey agencies.

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To analyze and correct bias from landline telephone undercoverage, some researchers use face-to-face surveys which contain questions on landline ownership and registration (e.g., Joye et al., 2012; Mohorko et al., 2013; Sala & Lillini, 2014). However, face-to-face surveys are expensive and if these surveys suffer from selective nonresponse the results then become questionable. For example, it is possible that households who own a listed landline are easier to reach by telephone than by face-to-face and may not be contacted using the face-to-face mode. In addition, telephone households may be more willing to participate (Sala & Lillini, 2014). Other researchers use experimental data including telephone and face-to-face samples both drawn independently at random (e.g., Holbrook et al., 2003). Nevertheless such experiments are also expensive and cannot replace large-scale social surveys. Other researchers also use a landline survey and, in addition, sample mobile-only members (e.g., Link et al., 2007; Lohr & Brick, 2014; Schneiderat & Schlinzig, 2012). Nonetheless interviews using mobile phones generally suffer from high nonresponse rates (Schneiderat & Schlinzig, 2012). In addition it still remains unknown whether the data quality of social science surveys via mobile phone is sufficient due to location issues, voice quality and net availability aspects, third party influence on socially desired answers (Kühne & Häder, 2012), or other factors affecting measurement errors (Lynn & Kaminska, 2012). Finally, extending a landline sampling frame to include mobile phones is not an easy task in European countries (Heckel & Wiese, 2012).

An alternative to analyzing and correcting bias from landline telephone undercoverage is to use additional survey modes to approach sample members without access to a landline (e.g., Cobben, 2009). However, knowledge about the extent to which sample representation can be improved due to the inclusion of additional survey modes for those without access to the primary mode is scarce. In the present research, we analyze bias from undercoverage and from nonresponse using a general population mixed mode survey, where the landline is the mode for households with a landline, and face-to-face for those without. The sample of this survey was drawn from a population register which includes basic socio-demographic variables, in addition to fully covering the population. Specifically, we analyze to what extent 1. the additional mode is able to decrease the number of errors from undercoverage in the telephone sample, 2. errors from the two main components of nonresponse, non-contact and non-cooperation, can be decreased by adding the face-to-face mode, 3. substantive variables are different in the telephone-only compared with the combined sample. As for 2., to distinguish non-contact and non-cooperation is not common in the literature (e.g., Peytchev et al., 2011; but see Cobben, 2009 and Olson, 2007), even though this distinction was previously noted over sixty years ago (Deming, 1947).

The article is organized as follows. First, we introduce the data and the socio-demographic frame variables. Next, we model bias in the frame variables accord-

ing to the different reasons for nonobservation. We compare predicted probabilities from multivariate logit models distinguishing the telephone and the combined telephone/face-to-face sample, and the fieldwork phases of, first, recruiting households and, second, recruiting enumerated household members. Finally, we analyze income and deprivation differences when either including the face-to-face sample members or not. The final chapter concludes with sampling and fieldwork considerations.

2 Data

For this research we use survey and register data from Switzerland. The Swiss case is interesting, since the percentage of research turnover via the telephone is amongst the highest in Europe (Häder et al., 2012). Nevertheless we believe that our findings are generalizable to other countries where formerly high landline coverage rates are declining and also to surveys in which the face-to-face mode is used to contact households without a telephone. In addition the different language regions in Switzerland add variance: they not only have different landline coverage rates, but are characterized by different cultural backgrounds and behaviors. Finally, unlike most other (European) countries, a harmonized sampling frame is available based on population registers from which the Swiss Federal Statistical Office (SFSO) draws samples for specific surveys, including the Swiss Household Panel (SHP).

We use data from the SHP 2013 refreshment sample (SHP III). The SHP is a nationwide, annual panel survey, which started in 1999 with slightly more than 5,000 randomly selected households using the centralized telephone survey mode. Each year a letter announcing the survey is sent in advance to the sampled households. Then the household reference person, an adult with sufficient knowledge of the household, is asked to report the current household's composition in the grid questionnaire. Conditional to the completion of the household grid, all household members eligible for interview complete their individual questionnaires.

The SFSO drew the refreshment sample SHP III at random from the national register of individuals residing in Switzerland. The SHP III total sample comprises 11,110 persons aged 16 years and over, of which a random subsample of 9,048 persons was fielded.[2] All members registered in the same household as the sampled individuals can be identified via the household identifier. The register provides demographic information about all household members such as sex, age, nationality, civil status, and municipality, but no telephone numbers. These must be searched separately and matched to the sample. The SFSO matched the

2 We dropped seven cases, among which were five who were surveyed using the web mode or could not be matched with call data, and two whose marital status was missing.

Table 1 Variables from sampling frame and categories used

Variable	Categories
Household size	1 person, 2 persons, 3 persons, 4 or more persons
Age of youngest child in household	No child, 0-6 years, 7-17 years
Language region	Swiss-German, French, Italian
Size of municipality of residence	more than 100,000 inhabitants, 20-100,000 inhabitants, 10-20,000 inhabitants, 5-10,000 inhabitants, 2-5,000 inhabitants, less than 2,000 inhabitants
Age group	16-30 years, 31-44 years, 45-58 years, 59-72 years, 73+ years
Nationality	Swiss or Swiss born, foreigners from one of the neighboring countries (sharing one of the Swiss national languages), other foreigners*
Civil status	single and never married (referred to as single), married (including separated), divorced, widowed
Sex	Women, Men

* See Lipps et al. (2013) for reasons why these two foreigner groups need to be distinguished in nonresponse analyses.

sample against its own register of telephone numbers. 7,396 (66.6%) households with publicly listed landline numbers were matched. After dropping the ineligible[3] households, we arrived at an analysis sample of 8,098 interview eligible households, of which 5,485 (67.7%) were from the telephone sample, and 2,613 from the face-to-face sample. All household members from the age of 16 years on were survey eligible in the first wave of the SHP III households considered here. Unlike the previous samples, members of the SHP III sample were not asked to fill out the individual questionnaire in their first wave, but were sent a biographical paper and pencil questionnaire with a pre-stamped envelope together with an unconditional incentive of 10 Swiss Francs.

In table 1 we depict the variables available from the sampling frame and the categories used in the analysis.

The reason for including language regions is that households living in the French or Italian speaking area of Switzerland have a lower landline coverage rate than those in the Swiss-German speaking part (see, e.g., Lipps & Pekari 2016). In addition we are interested in in-house effects: because the fieldwork for the Swiss-

3 Address problems included empty or demolished houses, addresses of an institution or a secondary home, or matched telephone numbers that did not work, such as modems. Other ineligible sample members comprised of dead people or those having left the country (AAPOR, 2011).

German speaking part on the one hand and the French and the Italian speaking part on the other were conducted by different centers (of the same survey agency) there may be different results. Note that in the SHP, a household is defined as all people living together for a longer time span, having at least one common meal per week, and – perhaps most importantly – for whom the flat/house in question is their principal residence.

3 Modeling and Results

Using the fielded eligible households, for all frame variable characteristics we analyze the proportion of households still present after each recruitment step. We use the characteristics of the sampled individual to represent *individual* frame variables (age, nationality, marital status and sex)[4] on the household recruitment level. We distinguish bias due to unmatched telephone numbers, noncontact, and noncooperation, the latter two separated by the telephone matched sample alone and the telephone/face-to-face sample combined. We tested the dependency of subsequent models (e.g., cooperation can only be analyzed for people who are contacted) using probit models with a sample selection (Heckman selection models; see Cobben (2009) for its application to components of nonresponse). The estimated correlation between matching, contact and cooperation is significant on a 5%-level, but not on a 1%-level. Given our large sample sizes, we use independent logit models. In the following tables 2 and 4, we list predicted probabilities. Compared with beta-coefficients or odds ratios, predicted probabilities are comparable across models and easier to interpret (Mood, 2010).

3.1 Household Grid Level

In table 2 we depict average predicted probabilities from each step of nonobservation during the household recruitment phase. As a reading example, we find a telephone matching probability of 50.0% if every household in the data was treated as if they contained one-person (upper left figure). The probability of being in the sample after being asked to cooperate (and therefore the conditional response rate) would be 17.9% in the telephone sample, if the sample members were treated as if they were foreigners from a country other than a neighboring country. We describe significant (1%-level) differences between the categories of a variable when appropriate, but don't depict significance levels in table 2 due to readability.

4 In only three households (with 12 individuals of age 16 years or older), different communication languages are recoded for at least two household members. We therefore treat language as a household variable.

Table 2 Predicted probabilities during the household recruitment phase

[average predicted probabilities from logit model]	Teleph. match	Contact Teleph.	Contact All	Coop. Teleph.	Coop. All
1 Person	0.500	0.483	0.826	0.288	0.415
2 Persons	0.630	0.622	0.895	0.378	0.489
3 Persons	0.789	0.767	0.927	0.472	0.527
4+ Persons	0.856	0.839	0.950	0.583	0.606
no children in household	0.698	0.674	0.886	0.397	0.480
youngest child in HH 0-6 years old	0.527	0.518	0.884	0.343	0.517
youngest child in HH 7-17 years old	0.645	0.648	0.916	0.428	0.538
Language Swiss-German	0.686	0.671	0.894	0.403	0.493
Language French	0.666	0.640	0.899	0.392	0.499
Language Italian	0.604	0.575	0.805	0.395	0.468
Municipality size >100K	0.658	0.642	0.867	0.395	0.471
Municipality size 20-100K	0.670	0.654	0.879	0.416	0.497
Municipality size 10-20K	0.666	0.645	0.901	0.394	0.501
Municipality size 5-10K	0.679	0.661	0.894	0.380	0.472
Municipality size 2-5K	0.679	0.661	0.901	0.405	0.510
Municipality size <2K	0.716	0.696	0.905	0.415	0.504
16-30 years old	0.413	0.410	0.814	0.283	0.452
31-44 years old	0.506	0.478	0.826	0.309	0.450
45-58 years old	0.720	0.698	0.902	0.430	0.515
59-72 years old	0.859	0.843	0.945	0.535	0.566
73+ years old	0.906	0.894	0.974	0.467	0.486
Native Swiss or born in Switzerland	0.716	0.697	0.903	0.437	0.519
from a neighbor. country	0.588	0.578	0.848	0.333	0.463
from another country	0.493	0.472	0.850	0.179	0.334
single	0.691	0.664	0.887	0.389	0.486
married	0.675	0.665	0.900	0.414	0.507
widowed	0.711	0.694	0.911	0.390	0.467
divorced	0.621	0.607	0.872	0.382	0.481
Women	0.691	0.672	0.900	0.405	0.496
Men	0.663	0.645	0.881	0.394	0.490
McFadden Pseudo R-squared	0.209	0.208	0.127	0.083	0.036
Mean value all households	0.677	0.659	0.890	0.400	0.493

Data: SHP III (2013 refreshment sample, N (households) = 8,098).

Also, we focus more on effect sizes than significance levels because the latter depends heavily on sample sizes. To give an example, there is a conditional matching probability of 69.1% for single households (N=2,702), of 67.5% for married households (N=3,748), and of 71.1% for widowed households (N=689) (see column "Teleph. match", rows distinguishing marital status). Nevertheless, although the matching probability difference between single and married households (1.6% points) is smaller than that between married and widowed households (3.6% points), the former difference is significant while the latter is not.

For each nonobservation step, we define the representation bias of each socio-demographic group by the ratio of its predicted probability to the mean probability. These biases are shown in table 3. For example, the conditional matching probability of 50.0% of a one-person household over the sample mean of 67.7% (=0.739) gives an underrepresentation of 26.1%. In addition, we define as the nonobservation-specific representation bias the standard deviation of the representation bias across the groups (last row).[5] All telephone samples have a higher representation bias than the combined samples. By far the highest representation bias is provided in the first step by the unmatched telephone numbers (0.157). (Additional) bias from noncontact plays no role, and from noncooperation a minor one (0.181). In the combined samples, bias from noncontact and (additional) bias from noncooperation are similar and amount to 0.042 and 0.092, respectively.

In the following, we discuss the relevant representation biases of the frame variables, distinguished by the different steps of nonobservation.

Landline telephone matching (column "Teleph.match")

Overall, 67.7% of all fielded households can be matched with a landline number (table 2). The larger the household, the higher the match probability. One-person households have a 26.1% underrepresentation and four or more person households a 26.4% overrepresentation. Households without children and those with children from 7 years on are well represented, while those with small children are underrepresented by 22.2%. Concerning language, Italian speakers are underrepresented among the telephone matched households by 10.8%, which is in line with experiences made by the SFSO (e.g., Joye, 2012). Households in small municipalities (<2,000 inhabitants) are slightly overrepresented. The older the household the easier it can be matched with a listed telephone number, with the youngest group underrepresented by 39.0%, and the oldest group overrepresented by 33.8%. Native Swiss or people born in Switzerland are easier to match than foreigners from a neighboring country who are in turn easier to match than other foreigners. Finally, widowed households are easier to match than divorced.

5 Not to be confused with the R (representativity)-indicator, which is defined for all sample members, see e.g., Schouten et al. (2009). The R-indicator is defined as 1 - 2 * the standard deviation of the response probabilities. For convenience we use the standard deviation of the representation bias across the socio-demographic groups.

Table 3 Representation bias during the household recruitment phase

[average predicted probabilities / mean value]	Teleph. match	Contact Teleph.	Contact All	Coop. Teleph.	Coop. All
1 Person	0.739	0.733	0.928	0.720	0.842
2 Persons	0.931	0.944	1.006	0.945	0.992
3 Persons	1.165	1.164	1.042	1.180	1.069
4+ Persons	1.264	1.273	1.067	1.458	1.229
no children in household	1.031	1.023	0.996	0.993	0.974
youngest child in HH 0-6 years old	0.778	0.786	0.993	0.858	1.049
youngest child in HH 7-17 years old	0.953	0.983	1.029	1.070	1.091
Language Swiss-German	1.013	1.018	1.004	1.008	1.000
Language French	0.984	0.971	1.010	0.980	1.012
Language Italian	0.892	0.873	0.904	0.988	0.949
Municipality size >100K	0.972	0.974	0.974	0.988	0.955
Municipality size 20-100K	0.990	0.992	0.988	1.040	1.008
Municipality size 10-20K	0.984	0.979	1.012	0.985	1.016
Municipality size 5-10K	1.003	1.003	1.004	0.950	0.957
Municipality size 2-5K	1.003	1.003	1.012	1.013	1.034
Municipality size <2K	1.058	1.056	1.017	1.038	1.022
16-30 years old	0.610	0.622	0.915	0.708	0.917
31-44 years old	0.747	0.725	0.928	0.773	0.913
45-58 years old	1.064	1.059	1.013	1.075	1.045
59-72 years old	1.269	1.279	1.062	1.338	1.148
73+ years old	1.338	1.357	1.094	1.168	0.986
Native Swiss or born in Switzerland	1.058	1.058	1.015	1.093	1.053
from a neighbor. country	0.869	0.877	0.953	0.833	0.939
from another country	0.728	0.716	0.955	0.448	0.677
single	1.021	1.008	0.997	0.973	0.986
married	0.997	1.009	1.011	1.035	1.028
widowed	1.050	1.053	1.024	0.975	0.947
divorced	0.917	0.921	0.980	0.955	0.976
Women	1.021	1.020	1.011	1.013	1.006
Men	0.979	0.979	0.990	0.985	0.994
Standard deviation	0.157	0.160	0.042	0.181	0.092

Data: SHP III (2013 refreshment sample, N (households) = 8,098).

Noncontact (column "Contact Teleph." and "Contact All")
65.9% of all telephone fielded households can be successfully contacted (column "Contact Teleph." in table 2). Because of the high telephone contact rate (65.9/67.7=.973; CON1 according to AAPOR 2011), there is not much room for a large bias change due to the uncontacted telephone households. None of the groups change bias by more than 3% points. The only groups that change by more than 2% points are households with older children, who decrease their under-representation by 3.0% points, and 31-44 years old households, who increase their under-representation by 2.2% points.

Adding the face-to-face survey mode boosts the proportion of contacted households from 65.9% to 89.0% (column "Contact All" in table 2), which is a likely reason for the much smaller standard deviation of the representation bias (0.042) compared to the contacted telephone sample (0.160). For example, the underrepresentation of one-person households is reduced to 7.2%, of foreigners from another than a neighboring country to 4.5%, and of young households to 8.5%. Conversely, the overrepresentation of large households decreases to 6.7%, and of older households to 9.4%.

Noncooperation (column "Coop. Teleph." and "Coop. All")
40.0% of the eligible telephone sample members participate in the survey (column "Coop. Teleph." in table 2), which corresponds to a cooperation rate of 60.7% (=40.0/65.9; COOP1 according to AAPOR 2011). Substantial changes compared with the biases in the telephone contacted sample concern household size, age, and nationality in particular. Large households increase their overrepresentation by 18.5% points. Households without children decrease their underrepresentation (3.0% points) and are well represented in the sample of cooperating telephone households. While households with small children also decrease their underrepresentation (7.2% points), households with older children are now overrepresented. Italian speakers decrease their underrepresentation by 11.5% points and are now well represented. As for municipality sizes, there are small and nonlinear changes due to noncooperation. With respect to age groups, while young adults decrease their underrepresentation by 8.6% points and households between 31 and 44 years by 4.8% points, households between 59 and 72 years increase their overrepresentation by 5.9% points. Older people decrease it by 18.9% points. Native Swiss or people born in Switzerland increase their overrepresentation by 3.5% points, while foreigners from a neighboring country increase their underrepresentation by 4.5% points and other foreigners by 26.9% points. Widowed households decrease their overrepresentation by 7.8% points and are now well represented.

In the combined eligible sample (column "Coop. All" in table 2), 49.3% of the households participate (cooperation rate COOP1 55.4%). Small households see further losses due to noncooperation (8.6% points), while households with four or more persons increase their overrepresentation by 16.2% points. Households with small

children increase their (formerly well) representation by 5.5% points, and households with older children by 6.2% points. Language and municipality size play a minor role. As for age, households between 59-72 years increase their overrepresentation by 8.6 % points, and older households decrease it by 10.8% points and are now well represented. Native Swiss or people born in Switzerland increase their overrepresentation by 3.8% points, while foreigners from a country other than a neighboring country increase their underrepresentation by 27.8% points. Finally, widowed households decrease their overrepresentation by 7.7% points and are now slightly underrepresented.

3.2 Person Level

We now turn to representation bias in terms of individual frame variables due to selective losses of individuals in households with a completed grid questionnaire. All enumerated individuals from the age of 16 years on are eligible for an interview. The 3,989 cooperating households report a total of 8,056 persons, of whom 7,826 were interview eligible and fielded. Similar to the household recruitment phase, we list predicted probabilities and representation bias for contact and cooperation, in table 4 and table 5, respectively.

85.1% of all enumerated interview eligible individuals can be contacted by telephone (column "Contact Teleph." in table 4). Similar to the household recruitment phase, the older the individual the easier it is to obtain contact. Contacted young adults are underrepresented by 7.5%, contacted older individuals overrepresented by 11.5%. As in the household recruitment phase, native Swiss or people born in Switzerland are easier to contact than foreigners from a neighboring country, who in turn are easier to contact than other foreigners. The latter are underrepresented by 22.4%. Unlike during the household recruitment phase, the widowed are more difficult to contact, but still slightly easier than divorced people. If face-to-face sample members are included (column "Contact All" in table 4), the individual specific contact rate boosts to 98.3%, which again leaves little room for representation bias.

Considering cooperation rates by telephone (column "Coop. Teleph."), people aged 73 years and over cooperate less than other age groups and change their overrepresentation from noncontact into underrepresentation. Foreigners from a neighboring country increase their underrepresentation by 4.6% points, other foreigners by 13.0% points. As for marital status, singles increase their underrepresentation by 3.8% points, and the divorced by 6.3% points. Including the face-to-face sample members increases the individual specific cooperation rate to 78.8% (table 4). Older people from 59 years on improve cooperation relatively less in the combined sample. The strongest improvements come from foreigners and especially those from a country other than a neighboring country, and younger and single people.

Table 4 Predicted probabilities during person recruitment phase

[average predicted probabilities from logit model]	Contact Teleph.	Contact All	Coop. Teleph.	Coop. All
16-30 years old	0.787	0.984	0.675	0.851
31-44 years old	0.770	0.981	0.640	0.833
45-58 years old	0.874	0.977	0.689	0.778
59-72 years old	0.949	0.989	0.709	0.749
73+ years old	0.948	0.988	0.603	0.652
Native Swiss or born in Switzerland	0.882	0.985	0.702	0.796
from a neighbor. country	0.767	0.972	0.573	0.755
from another country	0.660	0.977	0.433	0.729
single	0.834	0.977	0.631	0.762
married	0.874	0.987	0.705	0.806
widowed	0.807	0.966	0.636	0.765
divorced	0.776	0.980	0.569	0.739
Women	0.858	0.985	0.680	0.793
Men	0.843	0.981	0.659	0.781
McFadden Pseudo R-squared	0.119	0.019	0.032	0.020
Mean value all people	0.851	0.983	0.670	0.788

Data: SHP III (2013 refreshment sample, N (individuals) = 7,826).

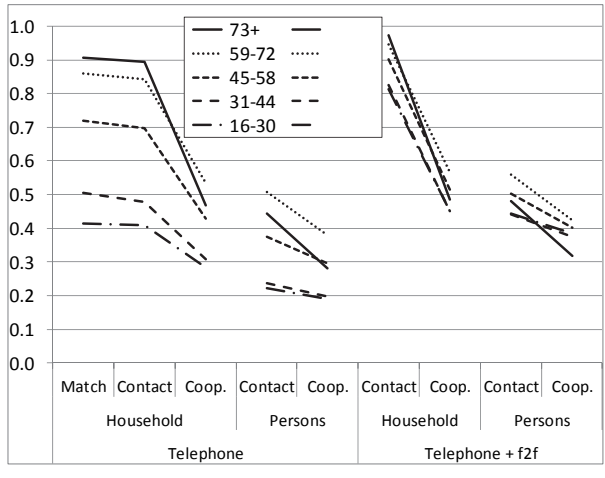
Looking at the representation bias in table 5, we note that the highest representation bias is due to noncontact errors in the telephone sample (0.087). (Additional) bias from noncooperation in the telephone sample is small (0.107). Bias from noncontact in the combined sample is again negligible (0.006) while (additional) bias from noncooperation is considerable (0.059).

When interpreting these findings, we must account for the fact that the final representation bias of the person groups is the sum of all the biases from the recruitment phases, i.e., from the household recruitment phase the bias from matching, noncontact, and noncooperation, and from the (subsequent) person recruitment phase the bias from noncontact and noncooperation. We illustrate this in figure 1 below using the example of old households aged 73 years or over.

Table 5 Representation bias during the person recruitment phase

[average predicted probabilities / mean value]	Contact Teleph.	Contact All	Coop. Teleph.	Coop. All
16-30 years old	0.925	1.001	1.007	1.080
31-44 years old	0.905	0.998	0.955	1.057
45-58 years old	1.027	0.994	1.028	0.987
59-72 years old	1.115	1.006	1.058	0.951
73+ years old	1.114	1.005	0.900	0.827
Native Swiss or born in Switzerland	1.036	1.002	1.048	1.010
from a neighbor. country	0.901	0.989	0.855	0.958
from another country	0.776	0.994	0.646	0.925
single	0.980	0.994	0.942	0.967
married	1.027	1.004	1.052	1.023
widowed	0.948	0.983	0.949	0.971
divorced	0.912	0.997	0.849	0.938
Women	1.008	1.002	1.015	1.006
Men	0.991	0.998	0.984	0.991
Standard deviation	0.087	0.006	0.107	0.059

Data: SHP III (2013 refreshment sample, N (individuals) = 7,826).



Data: SHP III (2013 refreshment sample, N (households) = 8,098, N (individuals) = 7,826).

Figure 1 Representation of households / persons by age due to reasons for nonobservation

Old households aged 73 years or over (solid line in figure 1) are overrepresented among the telephone matched households (+33.8%, see table 3), the telephone contacted households (+35.7%), and also among the contacted total sample (+9.4%). However, as they refuse more often these households are only slightly overrepresented among the telephone responding households (+16.8%), and well represented among the total responding households (-1.4%). Next, on the person recruitment level (table 5), old people are overrepresented among the telephone contacted people (+11.4%), while (still) well represented among the total contacted people (-1.2%). But after being asked to participate, they are underrepresented among the telephone respondents (-10.0%), and especially among the total respondents (-17.3%).

4 Deprivation: Telephone Versus Combined Sample

In this section we evaluate whether it is worth adding face-to-face households to the telephone households in terms of substantive variables, using deprivation as an example. We analyze regression coefficients from multivariate regressions with and without taking into account responding households without a telephone. We account for education level, age, the number of children under the age of 18 years in the household the number of adults in the household, and working status (full-time, part-time, retired, other). To this end, we analyze four deprivation variables:

- logarithm of household gross income (mean: 11.32)
- home ownership (49.8% of all households)
- a deprivation index, constructed as the number of items which the household cannot afford (car for private use (3.7%); savings into 3rd pillar (11.8%), dentist (2.7%), fresh fruit or vegetables (1%), and a room of one's own (2.1%))
- whether households were in arrears with their payments during the past 12 months (11.7%)

Table 6 shows regression coefficients of the face-to-face main- and interaction coefficients of the four regression models. Individual-level characteristics (education and working status) are taken from the household reference person. The models are controlled for the main effects of the interacted variables.

The sample sizes for income are smaller than the total respondent sample due to missing information. To test the effect of the survey mode on missing income, by means of a chi^2 test we find that these two variables are not significantly correlated (5% level). Although missing income is possibly affected in addition by mode

Table 6 Regression coefficients of face-to-face (F2F) dummies.

[beta-coefficients]	Ln Income (OLS)	Owner (logit)	Deprivat. (poisson)	Arrears (logit)
F2F main effect	-0.275**	-0.878*	0.982**	0.990*
F2F * education (11 categories)	-0.008	-0.031	-0.024	0.035
F2F * age (continuous)	0.002	0.020	0.010	0.012
F2F * number of children in household	-0.015	-0.151	0.008	-0.026
F2F * number of adults in household	0.034	-0.064	-0.009	-0.026
F2F * full-time employed	0.181**	0.453	-0.627**	-0.672*
F2F * part-time employed	0.060	0.627	-0.016	0.128
F2F * retired	-0.044	-0.411	-0.101	0.205
N	3,290	3,971	3,972	3,972

Data: SHP III (2013 refreshment sample, N (households) = 3,989 (740 f2f)). ** p<0.01, * p<0.05

selection effects, which we can only control for the variables at hand[6], this leads us to believe that mising income is independent of the mode. We find that the face-to-face households have a lower income, are less likely to be owners of their house, and suffer both from more deprivation and more payment arrears. The differences are substantial. For example, after controlling for all other variables in the model, face-to-face households have an 18.5% points lower probability of owning their house than telephone households. These findings are in line with the literature. As for interaction terms, only full-time employment plays a role: full-time employed face-to-face households have the same income as full-time employed telephone households (the sum of the face-to-face main effect and the face-to-face full-time interaction effect is statistically insignificant). The same is true for these households in terms of the deprivation index and the arrears. These results show that face-to-face households are poorer than telephone households on average, but that this does not hold for households with a full-time employed reference person.

6 For example, in a logit model regressing missing income on the survey mode, the coefficient of the survey mode hardly changes if the (negative) effect of education is also accounted for.

5 Summary and Discussion

Some surveys add a second mode to the landline to reduce issues from undercoverage while nonresponse remains a problem. To reduce bias from nonobservation, the idea of a responsive fieldwork design has recently been put forward (Groves & Heeringa, 2006): differences between observed and nonobserved sample members can be reduced by adjusting fieldwork efforts. Knowing the reason for nonobservation by mode facilitates fieldwork decisions. For example, higher noncooperation from a certain population group in mode A may be acceptable if this group exhibits higher coverage and contact rates in mode B.

In this paper we analyze socio-demographic representation bias on the basis of the different reasons for nonobservation, using a mixed-mode survey where the landline is used for households with a listed number and face-to-face otherwise. Some findings stand out in our analysis. People from one-person households and those with small children at home, young adults, and foreigners are more difficult to match, while the opposite is true especially for those living in large households and in particular older people. Additional bias from noncontact is small. Existing bias tends to increase when trying to obtain cooperation, with the exception of young households, who cooperate more often and older households, who cooperate less often. Adding the face-to-face mode largely decreases the bias. Still, the underrepresentation of one-person households and foreigners increases with each step. During the recruitment of eligible individuals in cooperating households, noncontact can be largely decreased by adding the face-to-face sample. Otherwise, existing bias from the household recruitment phase remains constant, with – again – the exception of older people, who are easier to contact by telephone but cooperate to a lesser extent in both samples. Foreigners from a country other than a neighboring country (and thus not sharing one of the survey languages) are both difficult to contact and to convince to participate, especially in the telephone sample.

We model income and deprivation of responding households for the telephone and the combined telephone / face-to-face sample. The result shows that the telephone respondents are richer on average and suffer from less deprivation, which also proves the importance of including the face-to-face mode in terms of substantive survey variables.

To optimize fieldwork, our findings imply that different socio-demographic groups should be treated differently according to their selective reason for dropping-out. First, more effort should be invested for groups with a low matching probability (one-person households, households with young children, Italian speaking households, young households, and foreigners). It may be an idea to use additional data sources (Lipps et al., 2015), manual researches, postcards asking for contact information (e.g., Lipps & Kissau, 2012), or less sensitive algorithms to match names. With respect to obtaining cooperation, more older and foreigner house-

holds, especially those from countries not sharing one of the survey languages, fall out of the sample. These groups should be treated with special care. One idea would be to use ethnic or bilingual interviewers (Kappelhof, 2015; Laganà et al., 2013), to approach them face-to-face to facilitate communication in a foreign language, or to provide an extra incentive. In the face-to-face sample, making contact is more difficult with one-person households, with Italian speakers, in large municipalities, and with foreigners from a neighboring country. This is probably due to no one being at home at typical calling times. More calls at different times and on different weekdays can be attempted with these households. Among the cooperating households, again there is underrepresentation in one person households, those without children, Italian speakers, those in large municipalities, older people, and the married[7]. A further idea could be to use more successful interviewers to visits these households, or again to offer incentives.

During the person recruitment phase in the contacted telephone sample, young people are underrepresented, as well as foreigners and especially those from countries not sharing one of the survey languages, and divorced people. Noncontact has a small effect on bias in the total sample. As for noncooperation in the telephone sample, refusals are more prevalent among people aged 73 or over, and foreigners from countries not sharing one of the survey languages. In the face-to-face sample, people aged 59-72 years refuse more often. To reduce bias caused in the person recruitment phase, similar measures to the "critical" households during the household recruitment phase should be taken, with perhaps more "person-tailored" measures.

We here note some limitations of this paper. Evidently, bias can only be analyzed for the representativity of the socio-demographic variables available from the population register. While these variables reflect household at-home patterns and are suitable for analyzing noncontact, non-cooperation depends on social participation and interest in societal well-being (Stoop, 2005). Because socio-demographic variables are "correlates, not causes of the survey participatory behavior" (Groves & Couper, 1996, p. 81), other register variables could be matched to sample members. While this was successfully done in Northern European countries (e.g., Nordberg et al., 2001), experiences from other countries are in their infancy and still restricted to specific domains like employment (e.g., De Gregorio et al., 2014).

In addition, the composition of the samples during fieldwork of course depends on the effort made in the previous steps, including the sources used to match telephone numbers and also the algorithm used to match telephone numbers. Similarly, effects from one mode depend on effort from another mode. As far as they go the results are therefore not easily generalizable. Our research is just one example to be used to shed light on the characteristics of sample members lost at the different

7 Note that married people are overrepresented from the other reasons for nonobservation.

steps during the survey recruitment phases in a mixed mode survey, and to show which steps require special care to keep socio-demographic representation bias at a reasonable level. More comparable mixed-mode surveys are needed to assess the fieldwork quality in the different modes, to find an optimal resource allocation for the modes, and to balance selective losses due to the different reasons for nonobservation.

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